

Having thus described the preferred embodiments, the invention is now claimed to be:

1. A gradient coil for a magnetic resonance imaging apparatus (10), the gradient coil including:

a primary coil (16) defining an inner cylindrical surface (60);

a shield coil (18) defining an outer cylindrical surface (62) coaxially aligned with the inner cylindrical surface (60) and having a larger cylindrical radius than the inner cylindrical surface (60); and

a plurality of coil jumps (74) electrically connecting the primary and shield coils (16, 18), the coil jumps (74) defining a non-planar current-sharing surface (64) extending between an inner contour (66) coinciding with the inner cylindrical surface (60) and an outer contour (68) coinciding with the outer cylindrical surface (62);

the primary coil (16), shield coil (18), and coil jumps (74) cooperatively defining a current path that passes across the current-sharing surface (64) between the inner and outer contours (66, 68) a plurality of times.

2. The gradient coil as set forth in claim 1, wherein:

the primary coil (16) extends axially a primary coil length ($2L_p$) along the inner cylindrical surface (60); and

the shield coil (18) extends axially a shield coil length ($2L_s$) along the outer cylindrical surface (62);

the shield coil length ($2L_s$) not equal to the primary coil length ($2L_p$).

3. The gradient coil as set forth in claim 2, wherein:

the current sharing surface (64) corresponds to a curved surface of a frustum of a cone with a cone angle (α) defined by a difference between radii (R_p , R_s) of the inner and outer cylindrical surfaces (60, 62) and a difference between the primary and shield coil lengths ($2L_p$, $2L_s$).

4. The gradient coil as set forth in claim 1, wherein: the inner and outer contours (66, 68) are circular contours, and the current-sharing surface (64) includes a conical surface portion extending between the inner and outer circular contours (66, 68).

5. The gradient coil as set forth in claim 1, wherein the primary coil (16) includes:

communicating primary coil turns (72) that electrically connect with a coil jump (74); and

isolated primary coil turns (70) that do not electrically connect with a coil jump (74).

6. The gradient coil as set forth in claim 5, wherein the shield coil (18) includes:

communicating shield coil turns (82) that electrically communicate with communicating primary coil turns (72) via connecting coil jumps (74).

7. The gradient coil as set forth in claim 5, wherein at least some of the isolated primary coil turns (70) are electrically interconnected to define an isolated primary sub-coil (P2), and the gradient coil further includes:

a switch having at least:

a first state in which the isolated primary sub-coil (P2) is electrically connected with the communicating primary coil turns (72), and

a second state in which the isolated primary sub-coil (P2) is electrically isolated from the communicating primary coil turns (72);

the first and second states corresponding to first and second selectable fields of view.

8. The gradient coil as set forth in claim 7, wherein the isolated primary sub-coil (P2) is deenergized in the second state.

9. The gradient coil as set forth in claim 7, wherein the isolated primary sub-coil (P2) is energized with opposite polarities in the two states.

10. The gradient coil as set forth in claim 7, wherein the gradient coil further includes:

a second shield coil (S2) that is energized in one of the two states to improve uniformity of the corresponding field of view.

11. The gradient coil as set forth in claim 5, wherein at least some isolated primary coil turns (70) are interconnected to define a selectively electrically switched primary sub-coil (P2), the gradient coil further including:

a second shield coil (S2, S2', S2'') that is selectively energized in conjunction with switching of the primary sub-coil (P2) to define a variable field of view.

12. The gradient coil as set forth in claim 1, further including:

a shielded correction coil that cooperatively adjusts a field of view over a continuous range.

13. The gradient coil as set forth in claim 1, further including:

a generally cylindrical cold shield (20) coaxially aligned with the outer cylindrical surface (62) and having a larger cylindrical radius (R_{cs}) than the outer cylindrical surface (62), the cold shield (20) carrying eddy current that produces a substantially spatially constant residual eddy current effect.

14. The gradient coil as set forth in claim 13, wherein the substantially spatially constant residual eddy current effect is non-zero.

15. The gradient coil as set forth in claim 1, wherein the gradient coil is a transverse gradient coil.

16. The gradient coil as set forth in claim 1, wherein the coil jumps (74) are selected to minimize the stored energy of the coil (16, 18, 74).

17. A magnetic resonance scanner comprising:

a main magnet for generating a temporally constant magnetic field;

a gradient coil as set forth in claim 1 for inducing magnetic field gradients across the temporally constant magnetic field;

at least one RF coil disposed adjacent the gradient coil;

an RF transmitter connected with one of the RF coils for inducing and manipulating resonance;

an RF receiver connected with one of the RF coils for demodulating induced resonance; and

a reconstruction processor for reconstructing the demodulated resonance into an image representation.

18. A method for producing a magnetic field gradient in a magnet bore (14) of a magnetic resonance imaging apparatus (10), the method including:

circulating an electrical current through a primary coil (16) that defines an inner cylindrical surface (60);

circulating the electrical current through a shield coil (18) that defines an outer cylindrical surface (62) coaxially aligned with the inner cylindrical surface (60) and having a larger cylindrical radius than the inner cylindrical surface (60); and

communicating the electrical current back and forth between the primary and shield coils (16, 18) via a plurality of non-planar coil jumps (74) a plurality of times.

19. The method as set forth in claim 18, further including:

selecting a total number of coil jumps (74) which minimizes the stored energy of the gradient coil (16, 18, 74).

20. The method as set forth in claim 19, wherein the selecting of a total number of coil jumps (74) includes:

constraining selection of the coil jumps (74) to produce substantially spatially constant residual eddy current effect from a cold shield (20) that surrounds the shield coil.

21. The method as set forth in claim 18, further including:

computing current densities on the inner and outer cylindrical surfaces (60, 62) using constraints including minimizing stored energy and minimizing the variation of the

residual eddy current effect, the current densities being generally non-zero at the inner and outer contours (66, 68);

arranging coil turns (70, 72, 80, 82) of the primary and shield coils (16, 18) to approximate the computed current densities on the inner and outer cylindrical surfaces (60, 62); and

during the arranging of coil turns (70, 72, 80, 82), arranging coil jumps (74) to approximate the computed non-zero current densities at the inner and outer contours (60, 62).

22. The method as set forth in claim 21, further including:

simultaneously with the computing of current densities on the inner and outer cylindrical surfaces (60, 62), computing current densities on a current-sharing surface (64), the arranging of coil jumps (74) being further constrained to approximate the computed current densities on the current-sharing surface (64).

23. The method as set forth in claim 21, wherein the computing of current densities further includes:

constraining the current densities to produce a substantially spatially constant eddy current effect produced by a current density in a cold shield (20) that surrounds the shield coil.

24. The method as set forth in claim 23, further including:

applying a gradient pre-emphasis that substantially cancels a magnetic field produced by the eddy currents in the cold shield (20).

25. The method as set forth in claim 18, wherein the primary coil (16) includes a plurality of coil loops (70, 72), the method further including:

selectively electrically isolating at least some primary coil loops (70) from the communicating of the electrical current between the primary and shield coils (16, 18) via the plurality of coil jumps (74), the selective electrical isolating defining a coil set which combined with a second shield coil (S₂) provides a second selectable field of view.

26. The method as set forth in claim 18, wherein the primary coil (16) includes a plurality of coil loops (70, 72), the method further including:

selectively removing at least some primary coil loops (70, 72) from the communicating of the electrical current between the primary and shield coils (16, 18) via the plurality of coil jumps (74), the selectively removed primary coil loops (70, 72) being interconnected to define a primary sub-coil (P2); and

circulating second electrical current through the primary sub-coil (P2) and a second shield coil (S₂''') the electrical current and the second electrical current cooperating to produce a gradient coil field of view that is different from a gradient coil field of view produced without the selective removing and circulating of second electrical current.

27. A method for designing a gradient coil for a magnetic resonance imaging apparatus (10), the method including:

computing current densities on coaxial inner and outer cylindrical surfaces (60, 62) using constraints on the stored energy and gradient field linearity and uniformity, the computed current densities being generally non-zero at non-coplanar boundary contours (66, 68) that define coil edges; and

selecting primary coil turns (70, 72), shield coil turns (80, 82), and coil jumps (74) to approximate the computed current densities on the inner and outer cylindrical surfaces (60, 62).

28. The method as set forth in claim 27, wherein the computing of current densities includes:

further constraining the computing to produce a substantially spatially constant eddy current effect produced by the eddy currents in a cylindrical cold shield (20) that surrounds the outer cylindrical surface (62).